

## A.2. SALINE PONDS OF LOS MONEGROS

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Wetlands in semiarid regions are striking features of the landscape when they occur in deserts or other drylands where water deficit strongly constrains life. In the semiarid region of Monegros, NE Spain, about 149 saline wetlands or “saladas” occur in karstic depressions. The area is ~70 km southeast of the city of Zaragoza, within the semiarid Central Ebro Basin, NE Spain. Although the environmental concerns of European Union blocked the irrigation works in Monegros for several years, and have enforced the exclusion of some areas from irrigation, the playa-lakes are being affected by the new infrastructures and dumping, land consolidation and intensive plow in non-irrigated lands.

Mean temperature is 14.9 °C. Low rainfall (mean= 334 mm yr<sup>-1</sup>) and high evaporation (mean reference evapotranspiration  $ET_0 = 1311 \text{ mm yr}^{-1}$ ) produce one of the highest mean annual water deficits in Europe. They host animals, plants, and microorganisms adapted to extreme conditions such as hypersalinity, high solar radiation, temperature extremes, and irregular, alternating periods of drought and flooding.

**Playa-lakes** and other **saline depressions** are expressions of solution dolines largely founded on groundwater dynamics and deflation, favored by the limestone and gypsum-rich substrate. Geology, topography and vegetation are key to understand the hydrological connectivity of

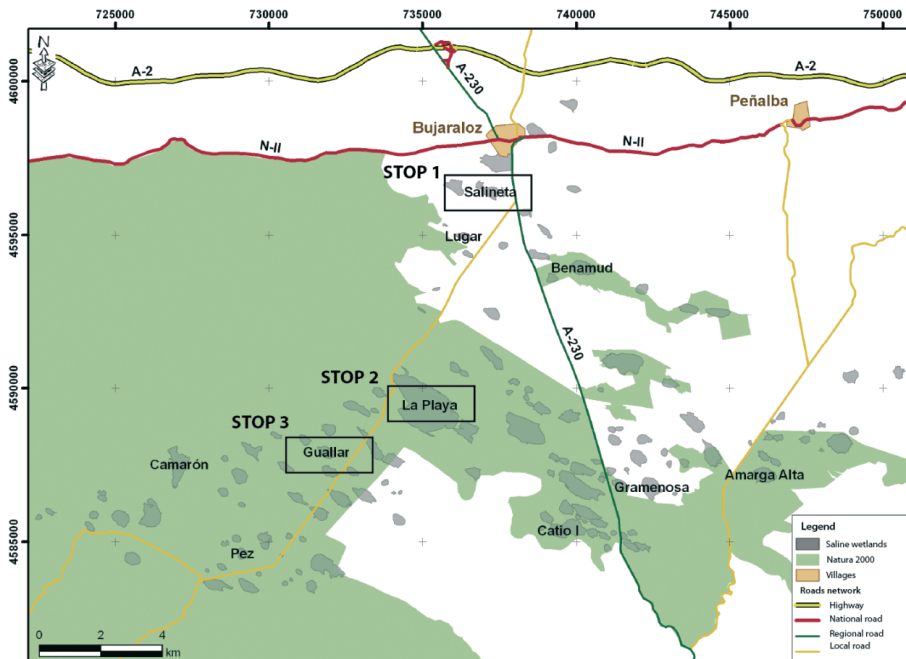


Fig. 1. Saline wetlands inventoried in the southern Monegros, NE Spain, in grey. Shaded area is excluded from irrigation. The three wetlands to be visited are indicated.

wetlands. Three Miocene gypsum-limestone units (lower, intermediate and upper) are separated by a continuous lutitic layer segregating the two main aquifers which have long water residence periods and furnish salty water to the playa floor. Monegros saline wetlands host ephemeral brines and their soils are waterlogged to moist, even in periods of hydric deficit, due to the proximity of a permanent shallow water table. The drivers of the high salinity of the groundwater ( $> 100 \text{ g L}^{-1}$ ) are: i) dissolution of soluble salts occurring in the geologic materials (especially in lutites), ii) high evapotranspiration, and iii) long residence time, between 10 and 100 years. Half of the water input into the wetlands comes from rains, a 40% from groundwater, and a 10% from surface runoff.

The saline wetland of southern Monegros are very dynamic environments providing habitats for rare and threatened plants and animals, and many studies have unveiled a large number of endemisms mainly of invertebrates, vascular plants, lichens, and bryophytes with the presence of active photosynthetic benthic microorganisms in magnesium sulfate-rich areas. The genetic identity and novelty of microbial extremophiles of this area remain largely unexplored. These saline lakes apparently contain quite abundant and new chlorophyta substantially different from any other green algae previously reported either in freshwater or in the sea. They are regulated by EU Habitats and Bird Directives and were included in the Ramsar list in 2011.

Around the bare floors there is a complex fringe of perennial and annual halophytes whose distribution depends on soil moisture and salinity. Halophytes, both perennials and annuals, were present in 91 (61%) of the Monegros saline wetlands. Xerohalophilous scrubs (*Arthrocnemum macrostachyum*, *Suaeda vera* subsp. *braun-blanquetii*, *Limonium delicatulum* subsp. *latebracteatum*, *L. cataunicum*) and grasses, particularly *Lygeum spartum*, *Puccinellia hispanica* predominate in saline soils, together with ephemeral plants (*Frankenia pulverulenta*, *Sphenopus divaricatus*, *Spergularia diandra*, *Haloepelis amplexicaulis*, *Salicornia patula*, *Microcnemum coralloides*). Other than the playas, the floors of the wetlands in depressions have xerohalophilous and halonitrophilous scrubs and grasses,

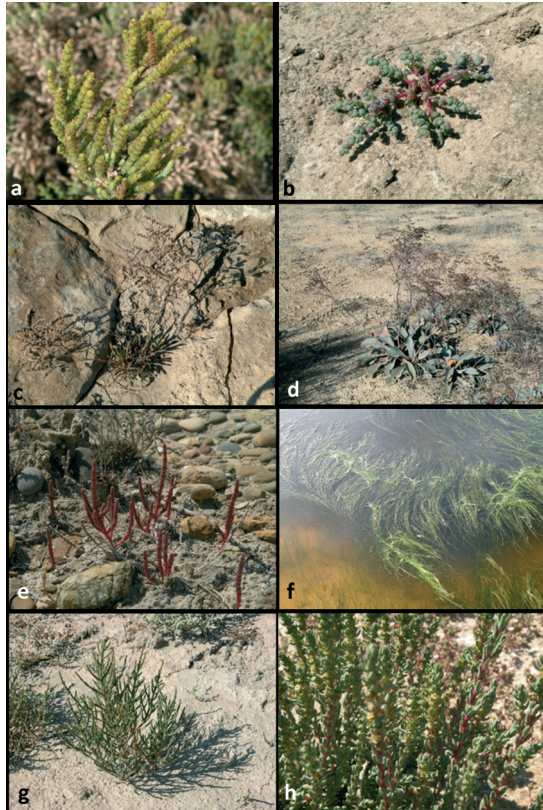


Figure 2. Main halophytes in Monegros saladas: a) *Arthrocnemum macrostachyum*; b) *Haloepelis amplexicaulis*; c) *Limonium costae*; d) *Limonium latebracteatum*; e) *Microcnemum coralloides*; f) *Ruppia drepanensis*; g) *Salicornia patula*; h) *Suaeda vera* subsp. *braun-blanquetii*

interspersed with meadows of halophilous therophytes or tamarisk communities (*Tamarix canariensis*).

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### STOP 1: SALINETA

This is one of the most striking wetlands of the endorheic complex. It is the northernmost and smallest playa-lake (~23 ha), with the greatest incidence of water and salts. Salineta is located on clayey materials, in the contact between gypsum rich and carbonate rich lutites. Salineta has an asymmetrical bottom aligned in the direction of the wind, and with ~90 cm of difference



Figure 3. a: Aerial view of Salineta in 2008; b: halophytes fringing the bare floor of Salineta, where salts are blowing out by the wind, in April 2012.

in elevation. Due to the wind, the mass of water is frequently found leeward of the area of greatest depth. Two crops of salt (summer and winter) were exploited in Salineta to the beginning of the last century, thenardite rich- and mirabilite rich-salt, respectively.

This wetland is the only playa-lake which may show a hydrological connection with both

aquifers on the platform, and drains a third part of the total upper aquifer discharge. The water occurrence obtained from remote sensing data was 98% of the 52 studied dates, from 1984 to 2004. Water salinity can reach 400 g L<sup>-1</sup>. Usually it cannot be walked on even in summer. Next irrigation installed in the area threatens the persistence of the vegetation and the microbial communities.

### Habitats and vegetation

Salineta includes ten habitats based on the CORINE Biotopes legend adapted to this territory (List of Habitats in Aragon, LHA) and five Habitats of EU interest (HIC), particularly HIC 1410 (*Juncetalia maritimi*). The bare saline bottom (code LHA 14.1) represents 84% of the wetland

extent. Flora includes about 150 species. Among them, *Halopeplis amplexicaulis* and *Microcnemum coralloides*, are catalogued as Threatened Species; *Juniperus thurifera* is of special interest; and *Limonium costae* and *L. delicatulum* subsp. *latebracteatum* have a high biogeographic interest. Main vegetation community is *Suaedetum braun-blanquetii*.

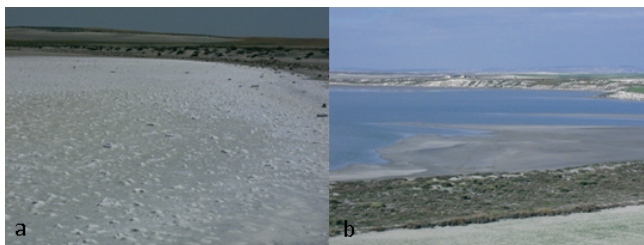


Figure 4. a: Salt crust in La Playa in 2005; b: view from the East, the halophytes fringing the playa floor.

## Preservation

Good conservation status and highest vulnerability due to its location in the future irrigated area (private ownership). Not included in the Ramsar list or even Natura 2000 Network.

## STOP 2: LA PLAYA

This is the largest salada of the endorheic complex, 2.7 km length and 240 ha of surface extent. Located at 325 m of elevation, this salada is hosted by an elongated solution doline which includes the neighboring salada, Pueyo. Both of them take part in the evolution of a complex system of yardangs (aeolian erosion) and lacustrine terraces, where yardangs develop on gypsum layers at the leeward margin of the playas.

This doline is connected with a dry valley 12 km length which crosses the platform conditioned by the two main fracturing directions in the area: NW-SE and NE-SW. La Playa has a water occurrence of 77% (from the 52 dates studied). The maximum water extent was registered in January 1987 (187 ha), and the maximum water depth was 51 cm in December 1994.

The floor is extremely flat, grading < 1.5 m. Some vestiges of the ancient salt exploitation in this saladas are preserved: at the lake floor there are parallel berms and plots for the cropping of salts, and ruined buildings included the quarter to guard the salt extracted, of royal property.

## Habitats and vegetation

La Playa includes thirteen habitats LHA and five HIC, 2 of them priority habitats: 1510 (*Limnietalia*) and 1520 (*Gypsophiletalia*). Other habitats are: 1310 (*Salicornia* and other annuals), 1420 (*Sarcocornietea fruticosi*). A 95 % of the salada are hypersaline habitats. The bare floor is the temporal habitat of biological communities of high ecological value, such as *Ruppia* (LHA 23.211). Is one of the seven saladas hosting the most tolerant perennial halophyte *Arthrocnemum macrostachyum* (LHA 15.613), extending in a 12% of the salada surface extent. There are between 225 and 250 phanerogam species, the highest of all the inventoried saladas. Threatened species are *Halopeplis amplexicaulis*, *Limonium stenophyllum* and *Microcnemum coralloides*. During flooding periods, characea (*Charetalia hispidae*) and *Ruppia* (*Ruppium drepanensis*) develop. The hepatic *Riccia crustata* has also been cited.

## Preservation

La Playa has an excellent conservation status; it is included in Natura 2000 and Ramsar list.

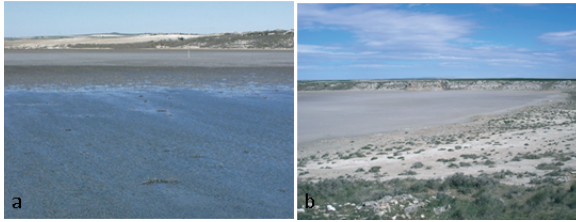


Figure 5. a: Sheet of water moved away from the scale by the wind; b: View of the dune (lunette) of Guallar, sparsely vegetated and the floor of the playa-lake, completely dry in 2012.

### STOP 3: GUALLAR

Guallar is a subelongated playa-lake of 15 ha located within a larger doline (uvala) and limited by an escarpment of about 10 m. At the SW, the depression is limited by a dune partially covered with vegetation.

This salada has a medium water occurrence (59%) and its maximum water depth was 26 cm in

February 1996. Soil salinity is  $> 60 \text{ dS m}^{-1}$  and the soil thickness varies between 80 cm at the dune and  $> 2.5 \text{ m}$  at the salada bottom. The vegetation covers a 40% of the salada extent, and red algal mats and evaporitic crust are frequent.

The study of sediments of selected saladas including Guallar permitted to establish vertical, lateral and regional variations in mineralogical and textural characteristics of palaeoenvironmental significance. From the three sedimentary units identified, the middle one records a lake stage with predominantly chemical sedimentation (Unit II), overlying an interval corresponding to a perennial lake stage with lower salinity (Unit III), whereas the surface unit formed during a period with predominantly clastic sedimentation. The middle unit was attributed to an Early Holocene humid stage, separated from the overlying Late Holocene deposits by a hiatus that corresponds to a Mid Holocene arid stage.

## Habitats and vegetation

Guallar include ten habitats LHA and four habitats HIC, two of them are priority habitats: 1510 (*Limnietalia*) and 1520 (*Gypsophiletalia*). The habitats of community interest occur in a 27% of the salada extent. During winter, the bare bottom is flooded favoring the developing of *Ruppia* (LHA 23.211).

There are between 150 and 175 phanerogam species, including *Halopeplis amplexicaulis* and *Microcnemum coralloides*, both of them catalogued as threatened. Other citations include *Senecio auricula* and *Ruppia drepanensis*, catalogued as vulnerable, and *Arthrocnemum macrostachyum*, found in the 1950s but now not present. During flooding events, there are also ephemeral aquatic communities such as characeae (*Charetalia hispidae*).